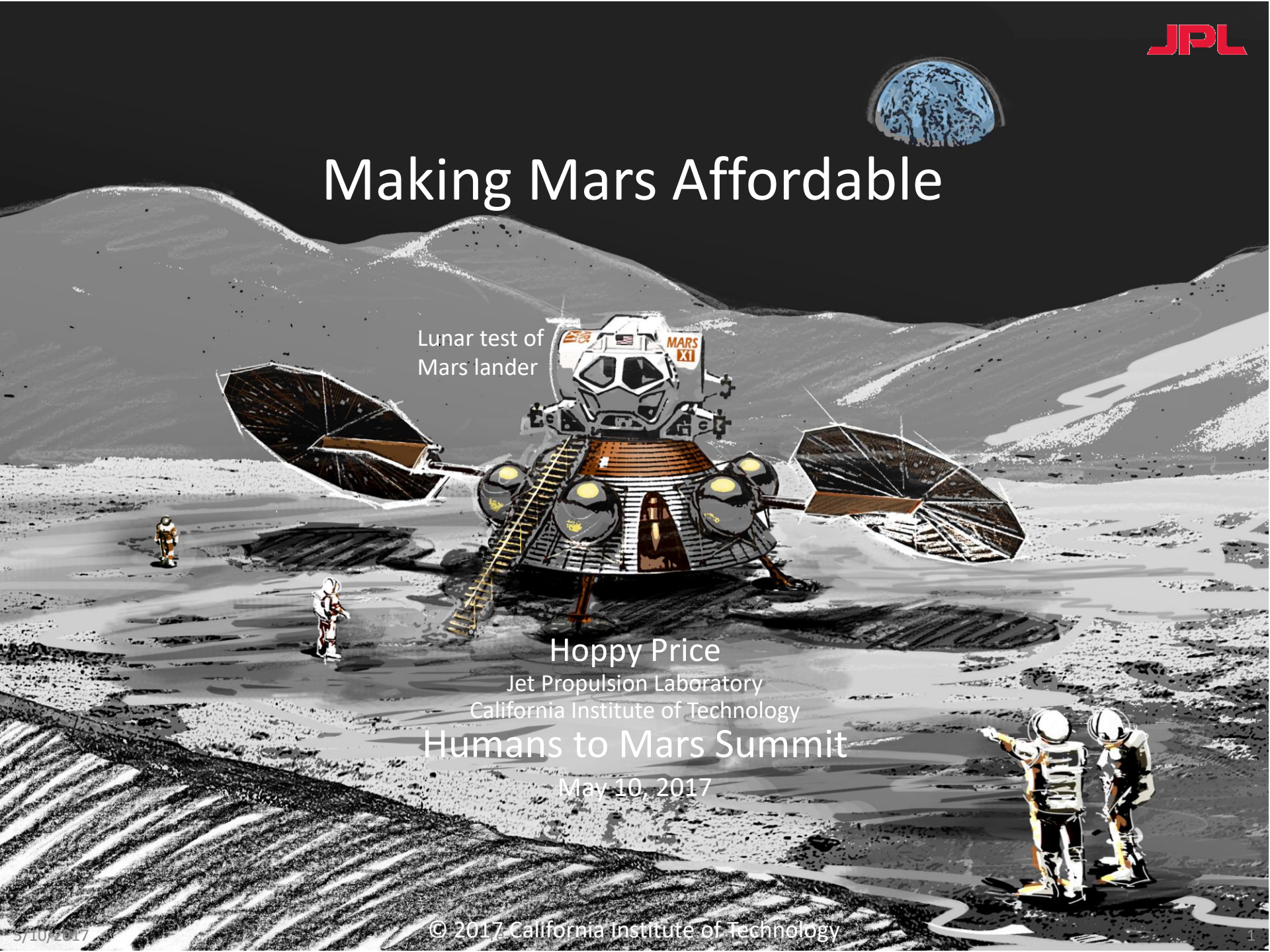
Making Mars Affordable



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Humans to Mars Summit

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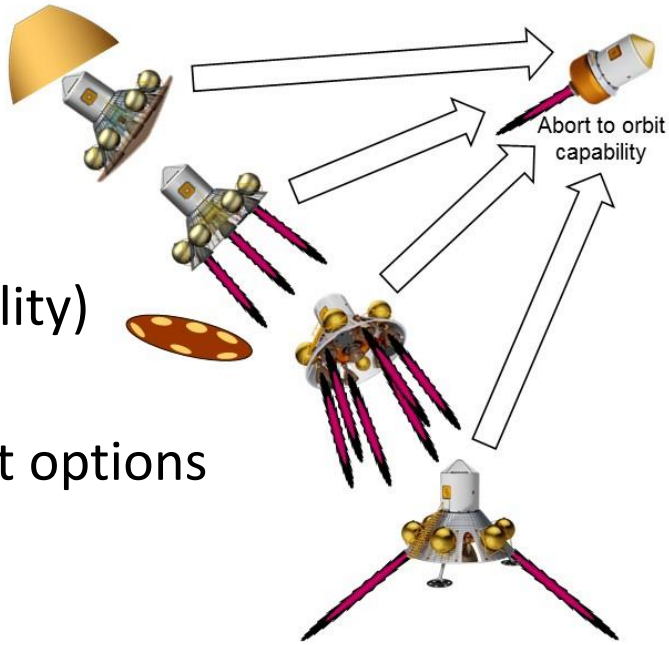
Affordability, Complexity, and Risk

- Mars is hard. Don't make it any harder than you have to.
  - Do the things you have to do to make the first missions safe and affordable on NASA's budget
  - Don't do things you don't have to do (e.g. complex enhancing technologies or features). Keep developing them, to be on-ramped later after risks of the initial missions have been retired.

Stuff You Really Have to Do

- SLS, Orion, and Ground System (they are near flight-ready)
- Deep Space Habitat (industry studies have begun)
- In-Space Propulsion (key decisions to be made)
  - High power SEP (~125 kWe) vs. very high power SEP (~450 kWe)
  - Cyrogenic vs. traditional hypergolic storable propellants
  - You might want to pick the safest and easiest options
- Lander (key decisions to be made)
  - Traditional capsule-type heat shield vs. HIAD
  - Storable vs. cryogenic propellants
  - Fully-fueled MAV (with abort to orbit capability) vs. ISRU-fueled MAV
  - You might want to pick the safest and easiest options



Technologies that Probably Aren't Required for the First Missions

- Capable, affordable, and sustainable crewed missions to Mars could be performed without these technologies:
  - In Situ Propellant Production (ISPP)
  - Very high power SEP (>150 kWe)
  - Zero-boil-off cryogenic propellants

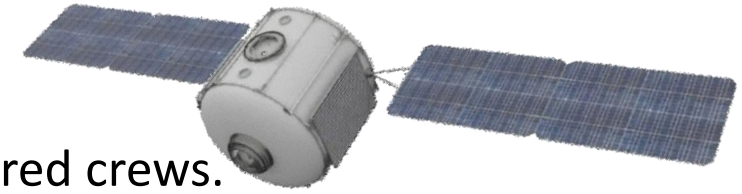
- After the first long-stay mission, a funding wedge for new developments should open up to on-ramp enhancing technologies
  - Mars food production might be more important than any of the items above, because that probably has greater value for permanent presence, crew quality-of-life, and morale
  - Indigenous water and oxygen for crews is probably easier and may be more important than making propellants.

Validate the Economics

- Which options are lower risk and more cost effective?
  - Only one chemical engine type vs. more than one type
    - In-space, descent, and ascent engines have different requirements for thrust, throttleability, and Isp
    - System costs for making one engine fit all may outweigh the "savings" of only developing one engine, especially if you can use existing engines for some of the applications

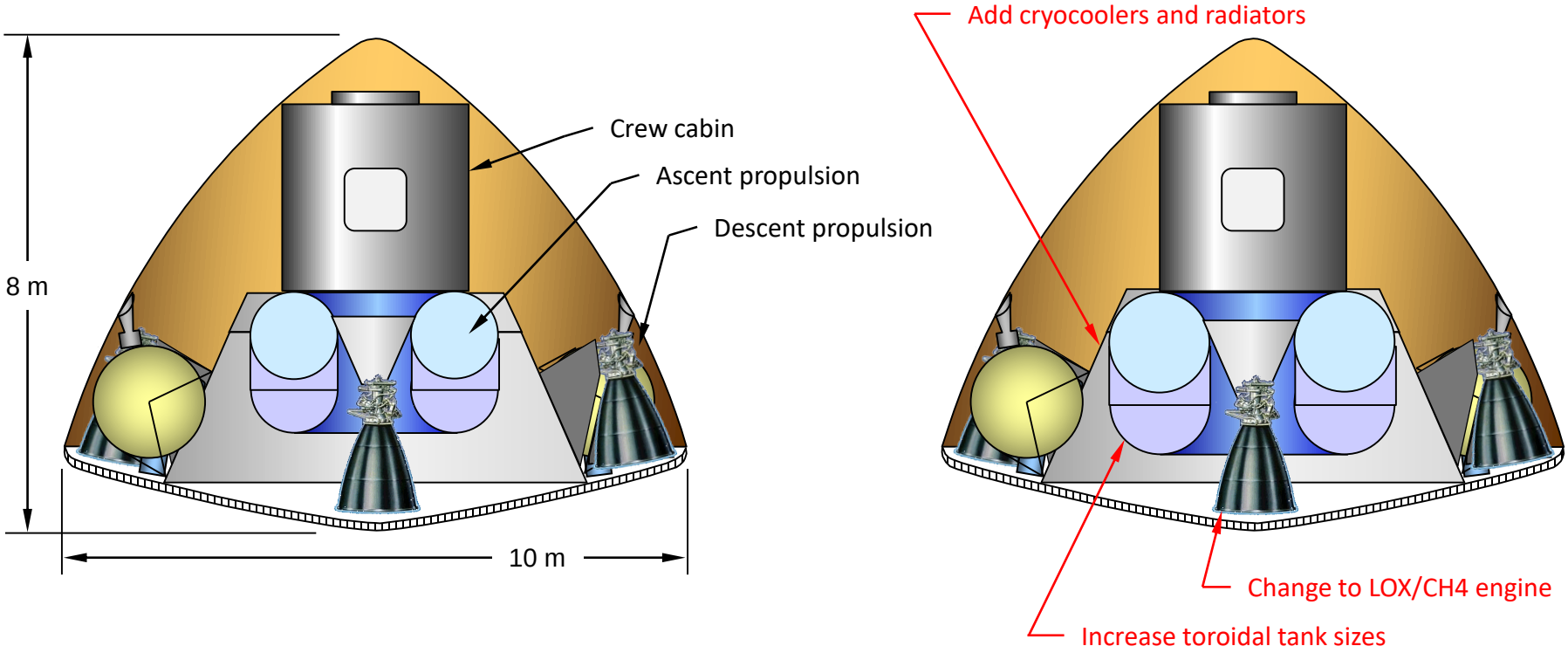
RS-72 Engine
Thrust = 55.4 kN
Isp = 340 s

  - Reusability vs. Expendable vs. Repurposing
    - Refueling and refurbishing vehicles in space to send back to Mars requires new technology, specialized support vehicles, infrastructure, and rocket launches. That carries cost and risk.
    - Economics and mission risk should be evaluated before committing to the complexity of reusability for the initial set of missions
    - As an alternative, returned Deep Space Habitats could be repurposed for crew training in LEO with commercially delivered crews.



Example of Later On-Ramping of New Technology:
Conversion of Capsule Lander MAV from Storable Propellants to Cryogenic ISPP

MMH/MON-15 → LOX/CH4



Note: Keep descent propulsion the same – MMH/MON-15